

# Hydrogen Infrastructure

## Opportunities for Accelerating Market Introduction of Hydrogen Fuels

Briefing to Steve Chalk

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# Topics

- **Hydrogen delivery volume**
- **HYDROGen INfrastructure Database (HYDROGIN)**
- Initial database capabilities
- Demo: Overlaying HYDROGIN onto other infrastructure databases
- Next steps

In 1999 the US Accounted for 3.2 tcf  
(1 quad) or 20% of Global H<sub>2</sub> Consumption

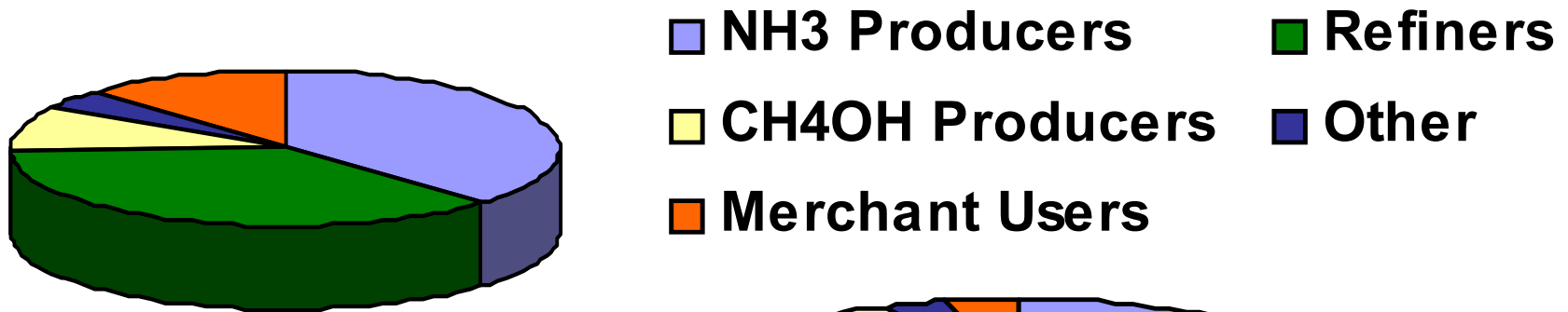
Captive Users	United States	Total World <sup>1</sup>
- NH <sub>3</sub> Producers	1.185	9.662
- Oil Refiners <sup>2</sup>	1.164	3.721
- Methanol Producers	0.303	1.428
- Other	0.121	0.482
Merchant Users	0.379	0.570
Total	3.153	15.864

<sup>1</sup> Including US.

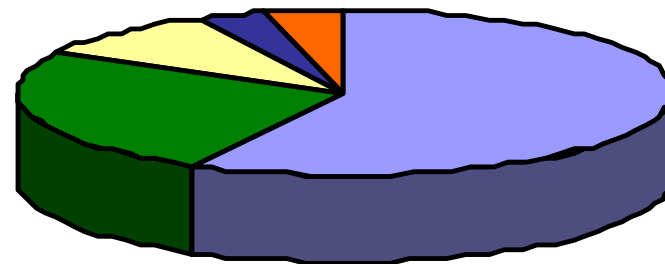
<sup>2</sup> Excluding byproduct hydrogen.

Source: SRI Chemical Economics Handbook 2001.

# Petroleum Refiners and Merchant Producers Play Bigger Roles in US Than Overseas



United States



Rest of World

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## Data Sources Used to Develop the Hydrogen Infrastructure Database (HYDROGIN):

- General locations and capacities of  $\text{GH}_2$ ,  $\text{LH}_2$ ,  $\text{NH}_3$  and methanol plants
  - *Chemical Economics Handbook* (SRI 2001)
  - *Chemical Profiles* (ChemExpo 2001)
  - *Chemical Profiles* (The Innovation Group 2001)
- Same for  $\text{GH}_2$ ,  $\text{LH}_2$ , G- $\text{LH}_2$  and methanol terminals
  - Web pages of individual companies
- General locations &  $\text{H}_2$  production capacities of refineries
  - *Data Book* (PennWell 2000)
  - "Refinery Capacity Data" (DOE/EIA 2001)

## Data Sources for HYDROGIN (cont'd)

- Geolocations of H<sub>2</sub>, methanol and NH<sub>3</sub> plants, terminals and delivery/receipt points
  - *Envirofacts Data Warehouse and Applications* (EPA)
  - *NPRI Data Search* (NPRI, Canada)
  - *Querying Canadian Geographical Names* (NRCan)
  - *Yellow Pages* (US & Canada)
- Geolocations of H<sub>2</sub> and NH<sub>3</sub> pipelines
  - H<sub>2</sub> from linking production and delivery/receipt points
  - NH<sub>3</sub> from *National Pipeline Mapping System* (USDOT 2001)

# Contents of HYDROGIN

	Production Plants (Number)	Storage Terminals (number)	Pipelines (miles)
GH <sub>2</sub>	81	14	560
LH <sub>2</sub>	10	3	na
GH <sub>2</sub> - LH <sub>2</sub>	na	3	na
Refineries	61	na	na
NH <sub>3</sub>	54	na	3105
Methanol	15	4	na
TOTAL	221	24	



# Data Coverage of HYDROGIN

	Plants	Terminals	Pipelines/ tank cars	Tanks/ Trailers
Nameplate capacity	√√√	√	√	√
Capacity utilization/ onstream factor	√	√	√	√
Onstream date	√√√			
Process	√√√			
Feedstock	√√√			
Delivery locations	√√		√√	

√√√ = Complete data.

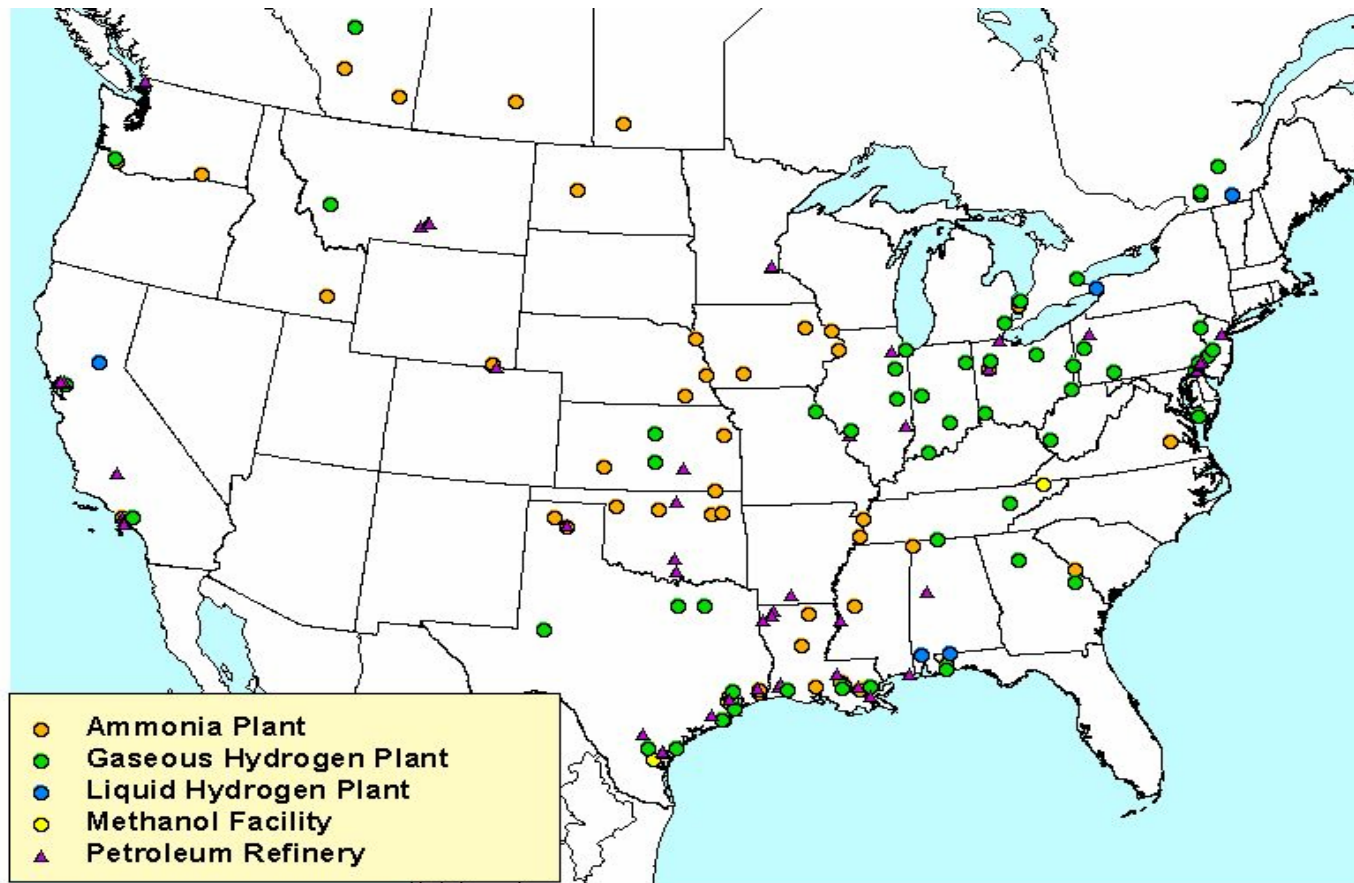
√√ = Partial data.

√ = No data.

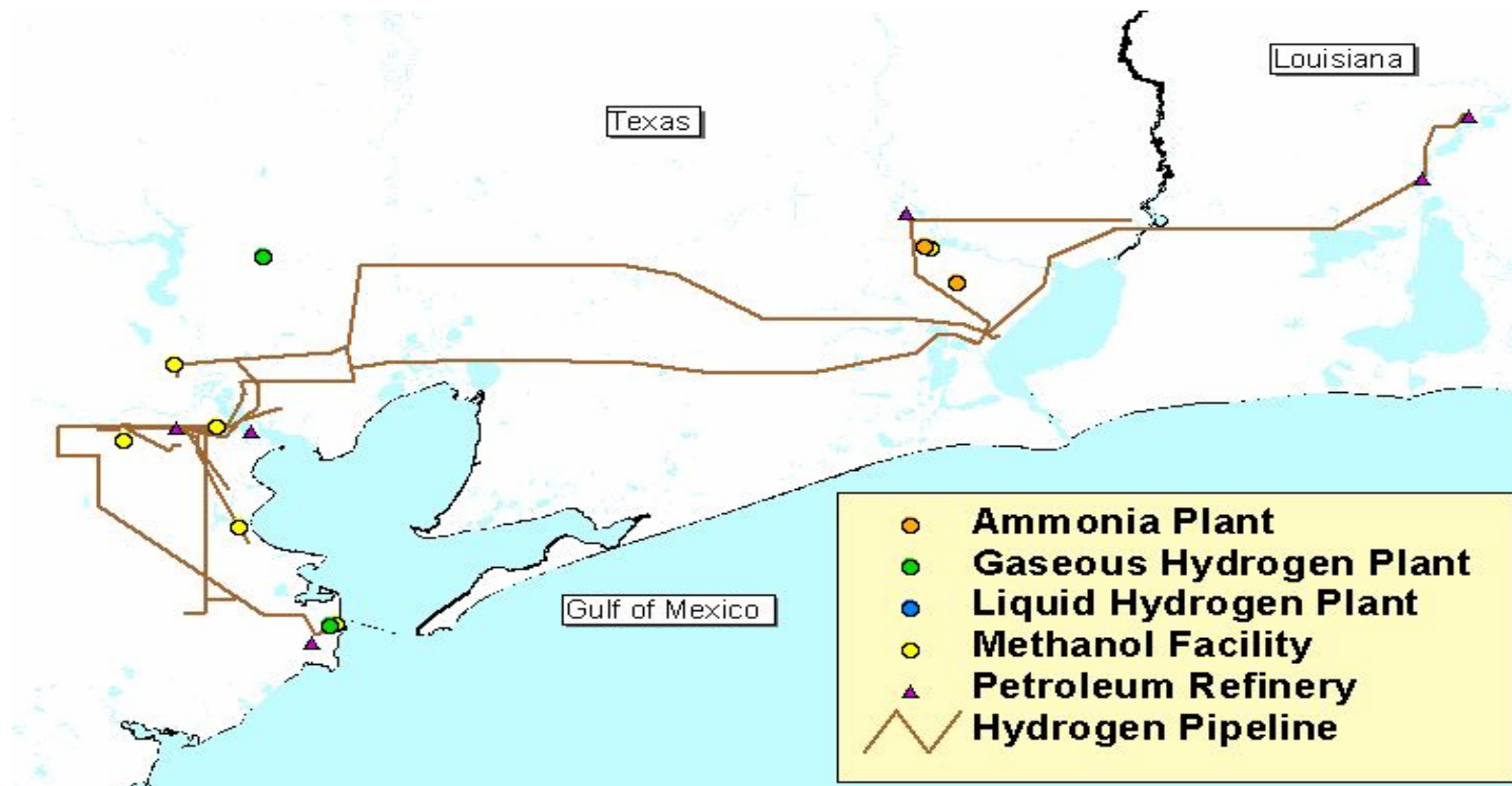
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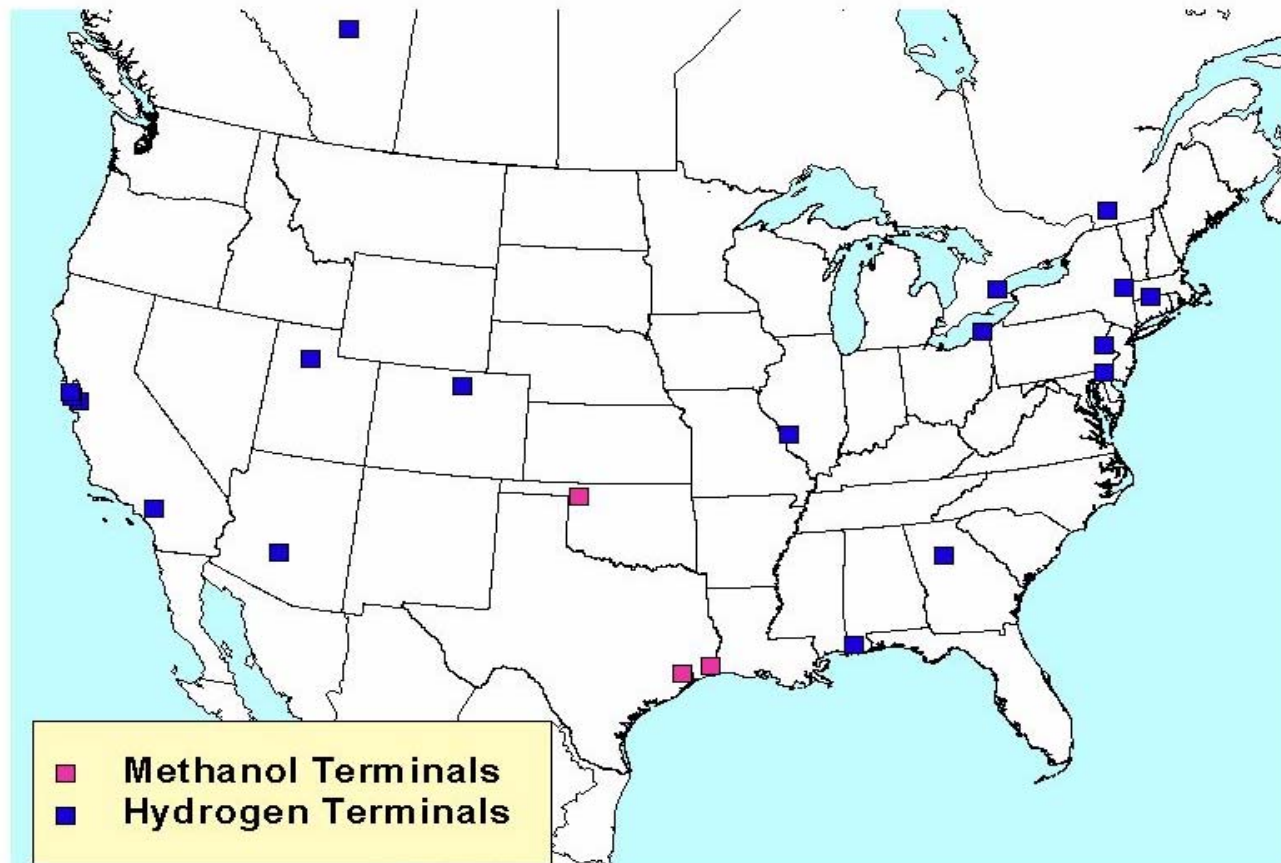
# Hydrogen Production Is Concentrated in Refining Centers and the Farm Belt



# H<sub>2</sub> Pipeline Segments Connect Plants with High-Volume Customers Many of Which Are Concentrated Along the TX/LA Coast

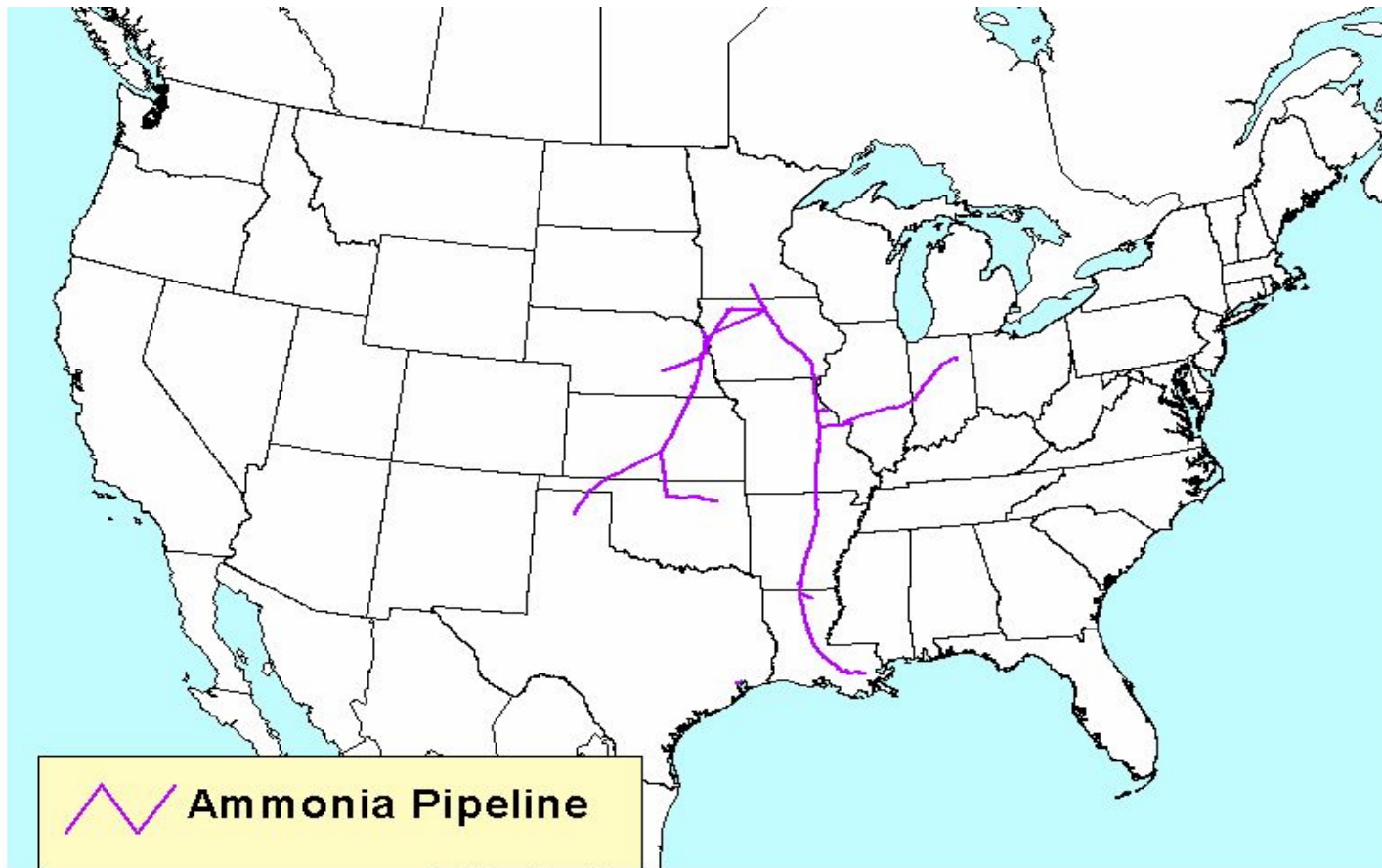


# Terminal Storage Can Be Co-Located with Production or Be at Remote Sites

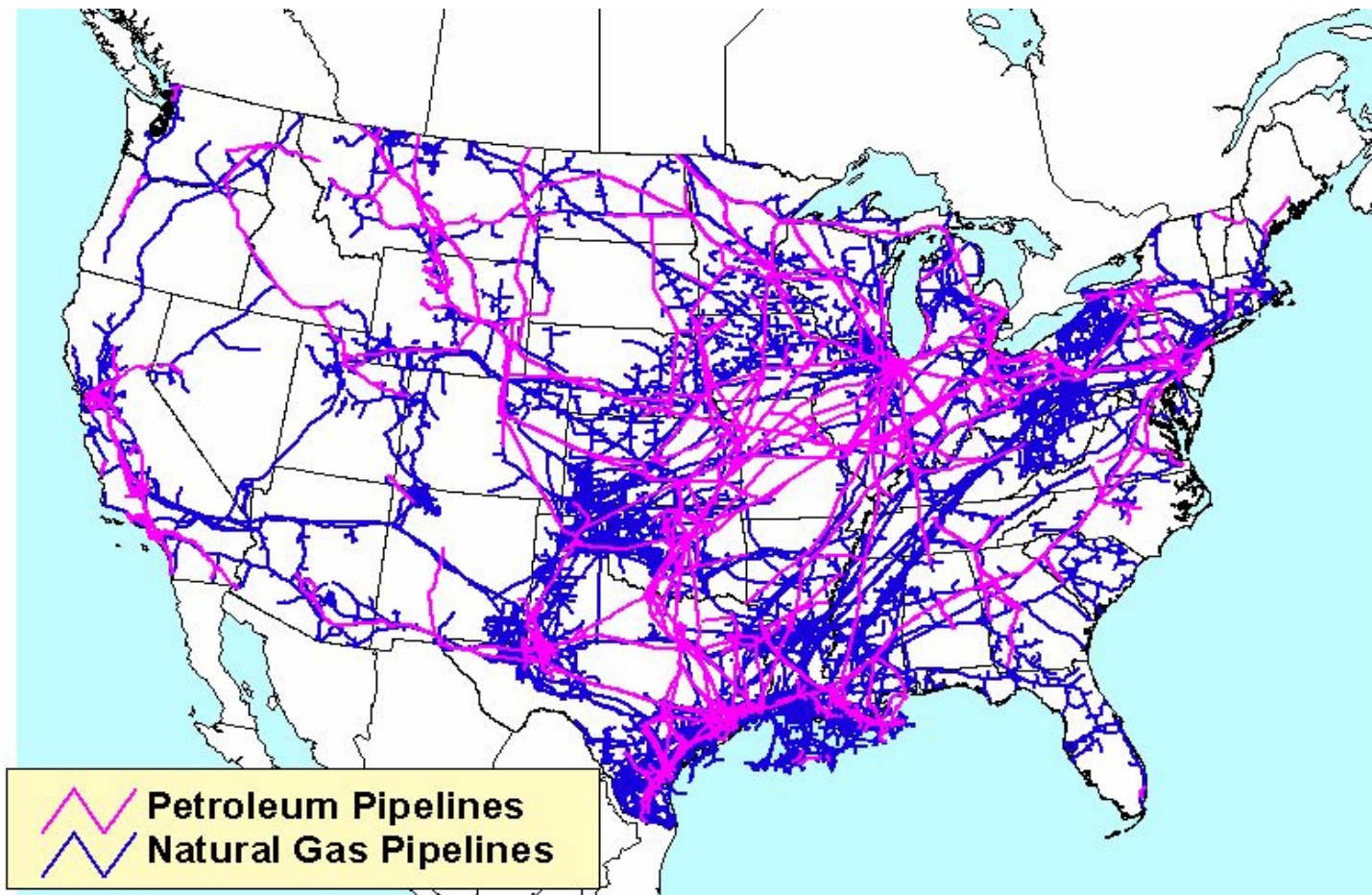




# Ammonia Pipelines Are More Extensive Than Hydrogen Pipelines



## But Pale in Comparison to Petroleum and Natural Gas Pipeline Systems



## In Addition to Plotting Existing H<sub>2</sub> Infrastructure, HYDROGIN Permits Various “What If” Analyses:

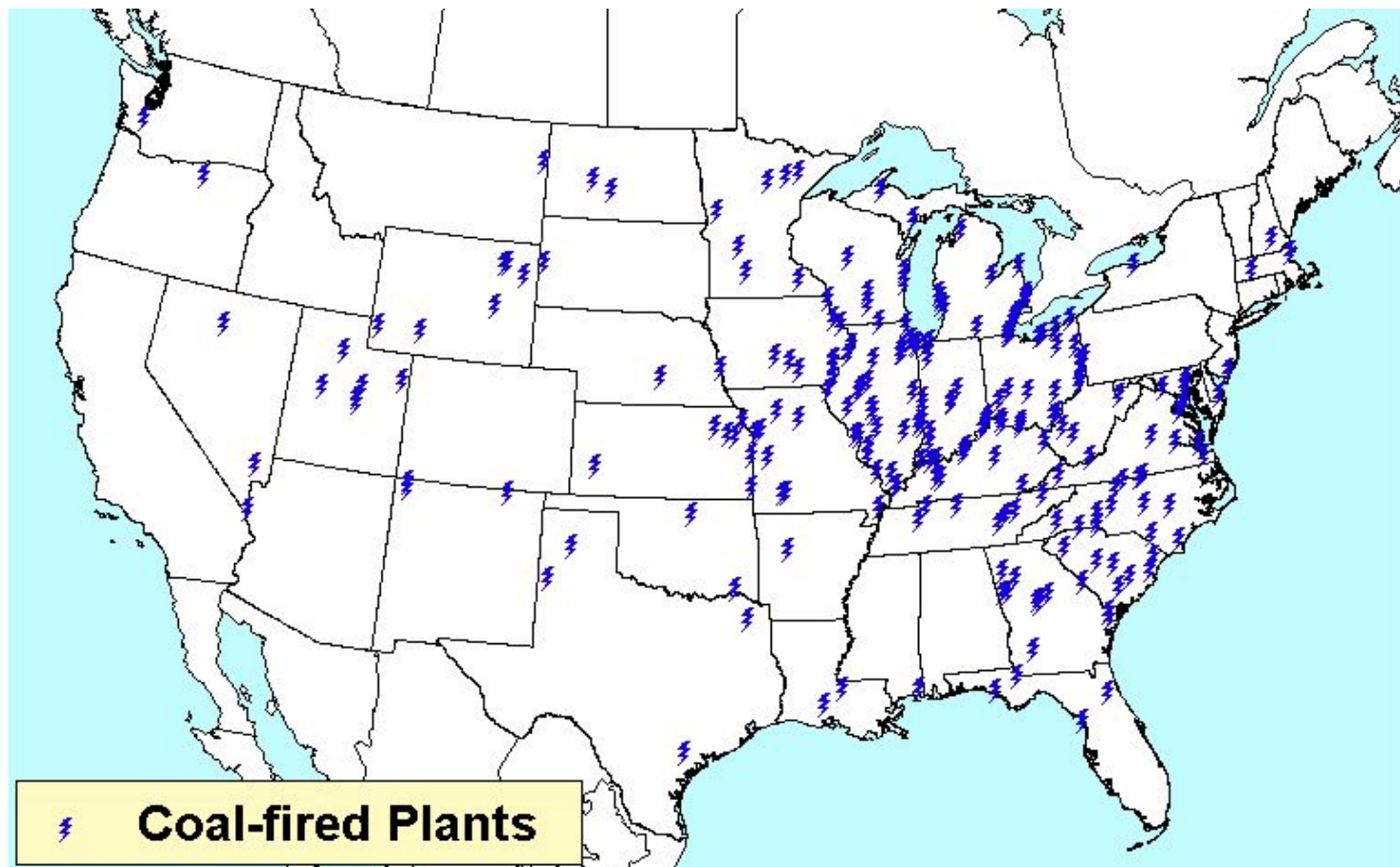
- What if a coal-to-hydrogen pathway were pursued?
- What if thermochemical water splitting were pursued using advanced high-temperature nuclear reactors?
- What if natural gas were reserved for transportation and coal or nuclear were shifted to power generation?

For all of these options:

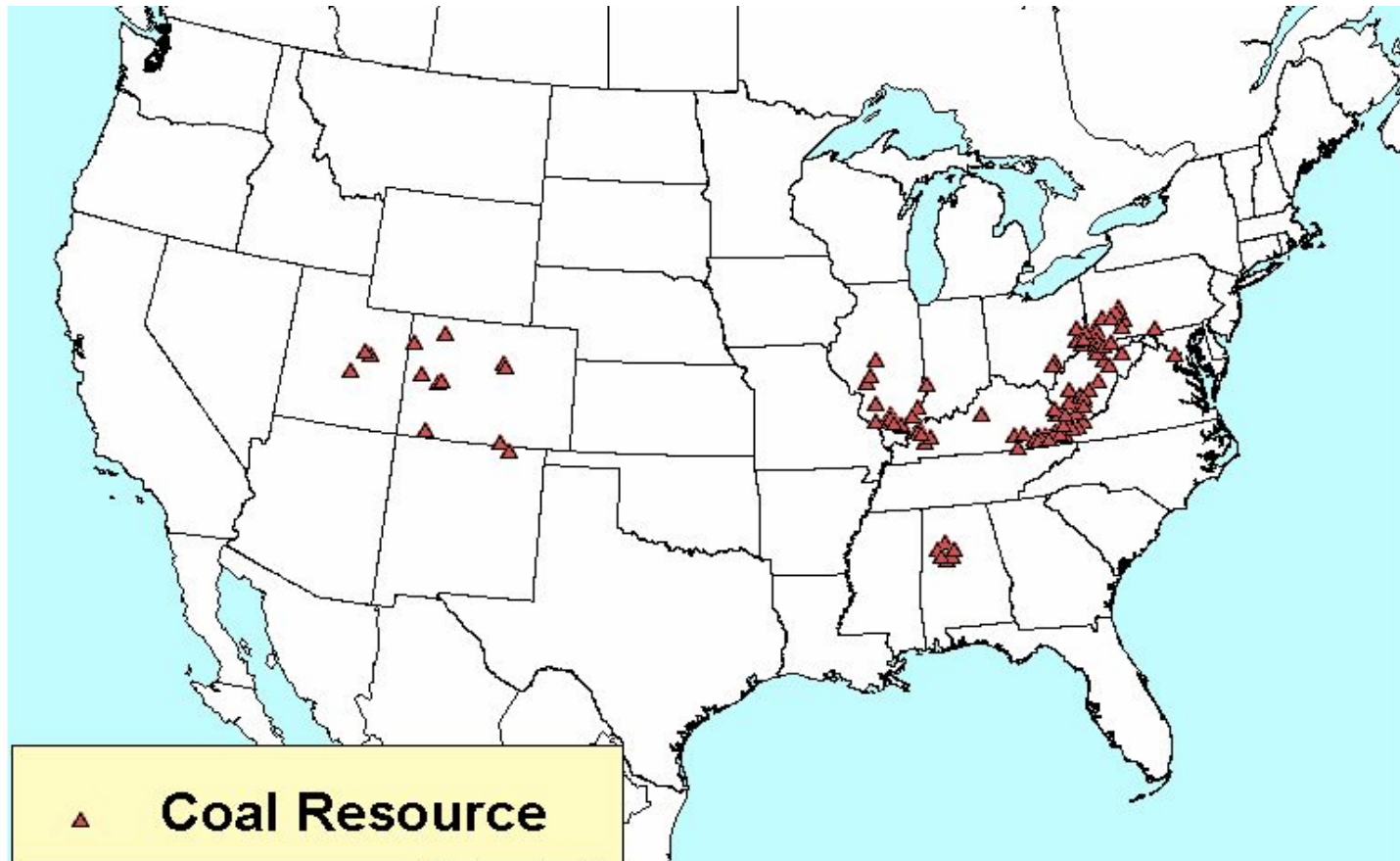
- Where would infrastructure develop and how might it evolve?
- What would it cost by itself and compared with other options?



## For a Coal-to-H<sub>2</sub> Pathway, the Mid-Atlantic and Ohio Valley Could Be Key Producing Regions

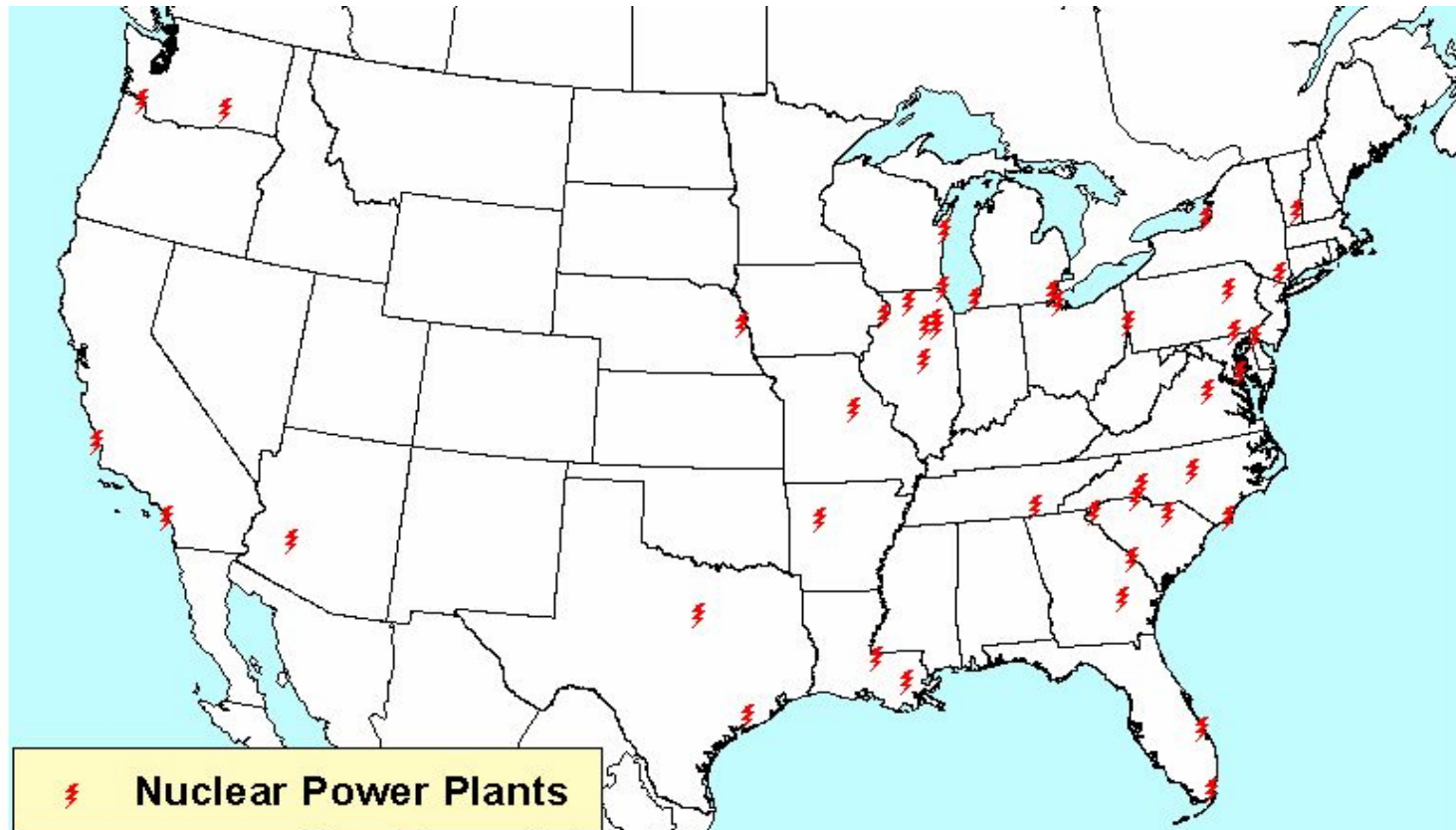


## Or, Use of Coal Bed Methane Could Move Production to a Subset of These States

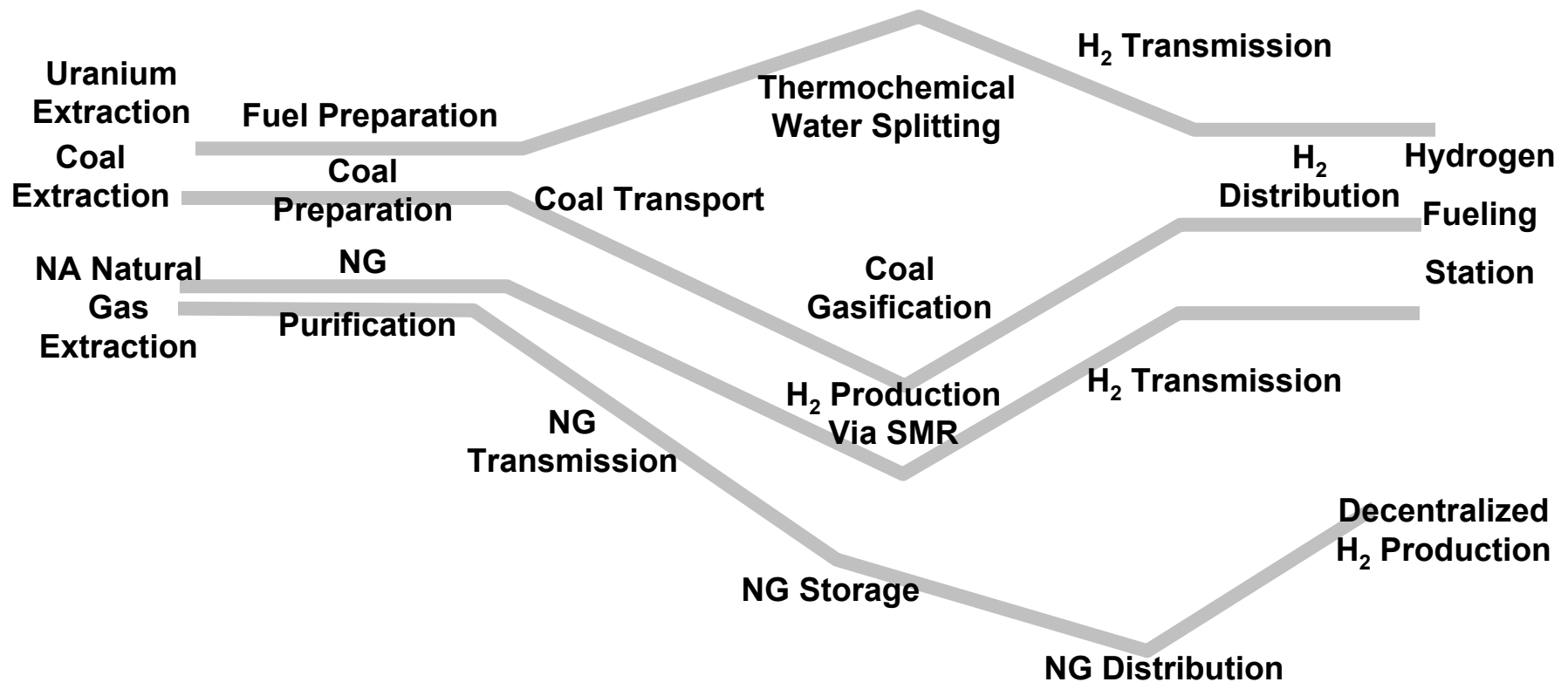




## For a Nuclear-to-Hydrogen Pathway, Producing Regions Could Lie Along Coastlines or Rivers



# In the 2050 Study, Four H<sub>2</sub> Pathways Were Modeled, But Production/Distribution Tradeoffs Were Data-Limited



## In Addition to Infrastructure, HYDROGIN Could Show Production, Capacity Utilization and Demand

- Similar maps of capacity, capacity utilization/unused capacity and abandoned capacity
- Locations of hydrogen-fueled vehicles (or other hydrogen end-users) and required deliverability

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# Next Steps

## Geocode infrastructure capacities

- 100 tpd vs. 1 tpd

## Estimate and geocode capacity utilization

- survey producers/operators
- Review/cross-check secondary sources

## Estimate marginal cost of capacity additions

- capital cost of modular additions
- supply curves

## Suggestions for Follow-On Work and Possible Collaborations

- Add cost modeling results to existing infrastructure cost model
- Integrate cost model with GREET, define additional pathways, and add them to HYDROGIN database
- Share HYDROGIN database and regional results with NREL for use in workshops and in developing regional demos
- Share HYDROGIN database and cost analyses with Ogden et al. in studies of infrastructure cost minimization
- Add interactive capability to permit users to investigate market potential of alternative pathways